WATER WORKS FOR FIRE PROTECTION[1]

By H. F. Blomquist[2]

The functions performed by water works may be considered as being three distinct services: (1) To furnish water for private use. (2) To furnish water for public use on streets and for sewers, public buildings, etc. (3) To furnish water for fire protection to property.

It is the aim of this paper to discuss some features that are often abused or neglected in connection with the fire protection service, calling attention to some principles of design of water works plants that should be observed in order to furnish a satisfactory fire protection service, and some statements in connection with the value of this service, and methods used by various municipalities for paying for it.

Amount of water for fire protection. From time to time during the past twenty-five years, standards for the amount of water required or desirable for fire protection have been suggested by different engineers. One of the first was John R. Freeman in 1892; later Allen Hazen and others in 1897; and the National Board of Fire Underwriters in 1910. Each of these gives formulas for determining the amount of water required for fire protection, and uses the number of inhabitants served as a basis for such calculations. The value of such formulas, however, may vary in different communities, because there is no fixed relationship between the population and the amount of water necessary to successfully put out a fire in the various communities. What may be good fire protection for one community of a given number of inhabitants, may not be for another of the same number of inhabitants because of the difference in construction of structures, nature of industries, and density of industrial sections, etc.

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A statement of the formulas proposed by these men may be of interest. According to John R. Freeman, in 1892, the total quantity of water required in gallons per minute equals 250 times $x/5$ plus 10 where x equals the number of thousands of inhabitants. According to Allen Hazen, in 1897, the quantity equals 700 times the square root of x, where x equals the number of thousands of inhabitants. According to the National Board of Fire Underwriters in 1910, the quantity equals 1020 times the square root of x multiplied by one minus 1/100 times the square root of x. These formulas vary somewhat, one from the other, but give an indication of what is considered a sufficient quantity of water that should be available for good fire protection.

Under the National Board of Fire Underwriters formula, the following figures give the required number of gallons per minute that should be available, 1000 population, 1000 gallons; 2000 population, 1500 gallons; 4000 population, 2000 gallons; 6000 population, 2500 gallons; 10,000 population, 3000 gallons; 13,000 population, 3500 gallons; 17,000 population, 4000 gallons; 22,000 population, 4500 gallons; 40,000 population, 6000 gallons; 80,000 population, 8000 gallons; 100,000 population, 9000 gallons; 125,000 population, 10,000 gallons; 150,000 population, 11,000 gallons; 200,000 population, 12,000 gallons. Over 200,000 population, 12,000 gallons per minute, with 2000 to 8000 gallons additional for a second fire. It is also desirable that the pipe system be of such design as to provide at least one-half of this amount for any one block of buildings, and in a greatly congested value district, the whole amount should be available for any one block.

Relations of the different parts of a plant. In order that proper results for fire protection may be obtained from the water works system it should be so designed that the maximum efficiency is obtained from all factors that enter into the furnishing of the water. Each of the following factors should have the proper relationship to the whole system: Source of supply, pumping equipment, reservoir or storage capacity, water pressure, distributing mains and the location of hydrants. Each of these is a link in a chain that supports the fire department in its efforts to put out a fire, and this support is no stronger than the weakest of the links. If the reservoir is of large capacity but the pipes are small, much of the cost of the reservoir is practically wasted. If the hydrants are not properly spaced the advantage of large distributing mains is to a considerable extent

lost. The spacing of hydrants and sizes of hydrant connections are very important in attaining high efficiency of a system for fire service.

Water pressure. The water pressure in the mains is of greatest importance if fire engines are not used, because a stream under heavy water pressure is very much more effective than one under low pressure, even though the same amount of water may be used on the fire. Unless water is applied to burning materials in buildings at a high velocity much of it does not reach the seat of the fire because of the difficulty of access and draft from burning gases. It is, then, either evaporated or decomposed into the two elements, hydrogen and oxygen, a part of which in turn combines with carbon of the burning materials and forms inflammable gases, which again burn. The water that does not reach the burning material is of little value, if any, and when transformed into gases may even be an aid to the flames rather than a means of putting them out.

In order to be of most value a fire stream must have a velocity that can be obtained only from a good pressure at the hose nozzle. As little as possible of the available pressure should be used up in hose and water system friction. It is, therefore, important that hydrants and mains should be of such sizes as to decrease as little as possible the water pressure at the hydrant nozzle by friction in the pipes, hydrants and connections during the time of heavy flow.

Friction in hose. The amount of pressure lost by friction or resistance in fire hose is a considerable item and varies very nearly as the square of the velocity or quantity of water flowing through. A few examples of the effect of this are shown by the following facts regarding the discharge of various lengths of 2½-inch rubber-lined cotton fire hose attached to a hydrant which has a constant pressure of 60 pounds at the hydrant nozzle. When a 1½-inch stream flows from a smooth bore nozzle with 100 feet of hose, it is possible to throw a stream of 250 gallons per minute 67 feet high; with 200 feet of hose this is reduced to 222 gallons per minute thrown 59 feet high; with 400 feet of hose it is reduced to 188 gallons per minute thrown 44 feet high; with 700 feet of hose it is reduced to 158 gallons per minute thrown 33 feet high, and with 1000 feet of hose it is reduced to 140 gallons per minute thrown only 25 feet high. It is, therefore, important that hydrants be spaced quite closely together in parts of towns and cities that are occupied by business or industries where fires are apt to be of a serious nature, in order that all available pressure may

be utilized in fighting the fire. There is a large waste of power in pumping all the water against a 60-pound head and getting only about 25 pounds effective pressure at the nozzle of a long line of hose.

The friction of water in fire hose is very often neglected. Long lines of hose are laid where short ones could be used and the water department sometimes is blamed for not maintaining a good water supply under proper pressure when the fault lies in poor judgment in locating the proper hydrants on which to make connections, and using much longer lines of hose than are necessary in reaching a fire. Of course, there are conditions where long lines of hose are absolutely necessary, but these conditions should be overcome as as much as possible by placing additional hydrants.

Reservoir capacity. The relation between the size of storage reservoir, pumping machinery, and source of supply must necessarily vary with local conditions, and for a well-balanced system a certain inverse ratio should exist between these factors. If it is possible to have a reservoir at an elevation to give the desired pressure and with a capacity sufficient to care for the heaviest fluctuations in the amount of water used for all possible emergencies, the pumping machinery and source of supply need not be of greater capacity than to safely take care of the average supply with a fair factor of safety, but if it is impossible to provide large storage of water for emergency uses, the water supply and pumping machinery must have sufficient capacity to furnish the required quantity during the time of the emergency. The possible size of the reservoir is affected generally by topography, and the desired capacity is governed by the facilities for pumping and the size of the available water supply.

The effect of the topography upon the design is often to change the reservoir from what is desirable to what is feasible. In a comparatively flat country it is impossible to store as much water as is desirable at a high elevation and in such cases the distributing reservoir must be reduced in size and other portions of the system, such as the available supply and the size of pumps, must be increased so as to do the work which should properly be done by the distributing reservoir.

For example, in a perfectly flat territory, where an elevated tank is the only feasible form of reservoir, it will at most be only a means of making it possible to store a part of the water that will be necessary for large fires, and, therefore, the main water supply must be

provided by pumping during the time of fire. In such a case it is necessary to have a supply and pumping capacity sufficient to furnish nearly all the water that will be required for fire protection at the time of the fire. If wells are used as the source of supply in such cases, a storage reservoir at a low elevation where it is convenient to build one, will serve as a suitable supply base. Where the topography is such that it is feasible to build a reservoir of any desired size and at proper elevation, the capacity is dependent almost entirely upon the requirements for fire protection.

The pressure furnished by the reservoir should be such as to give the required quantity of water at the proper pressure for fighting fires, and as this depends also on the size of the pipes, the pipe sizes and the reservoir pressure have a certain relationship one with the other and must be considered together. The cost of pumping water against a high pressure must also be considered in the design of reservoir and mains. Generally it is found that from 80 to 100 pounds per square inch is the most economic available pressure at points where there is likely to be the greatest demand for water. The elevation of the reservoir necessary to obtain this pressure will depend to a large extent upon the distance from the reservoir to the center of distribution and on the size of mains used.

The maximum desirable pressure is a matter on which there is much disagreement. For direct hydrant streams the National Board of Fire Underwriters recommends a pressure of at least 75 pounds at the hydrant when the water flows from it at its rated capacity, except that where not more than ten buildings exceed three stories a residual pressure of 60 pounds is permissible. In closely built residential districts a residual of 60 pounds is considered sufficient for direct hydrant streams, with 50 pounds in thinly built sections of low height. Where fire engines are used they recommend that the pressure on the full flow should not drop below 20 pounds, except a minimum pressure of 10 pounds is permissible under certain conditions. In small cities it is generally economical to maintain, if possible, a pressure of from 50 to 100 pounds in the system and thereby not require the use of fire engines for good fire protection. In large cities, instead of pumping all the water against the heavy pressure, it is more economical to maintain a lower pressure in the mains and to use fire engines to create the high pressure fire streams.

As stated before, the size of the reservoir must necessarily depend upon local conditions but should be, if possible, large enough to

hold at the required elevation, in addition to the domestic supply for 24 hours, a sufficient quantity of water with which to fight any fire that is likely to occur. A fire in the built-up portion of a small city may take from 1000 to 5000 gallons per minute, and in general the time during which this quantity will be required will not be more than from two to four hours. Applying this rule to the ordinary small city where there are no large fire risks the capacity of the reservoir or stand pipe should be from 120,000 to 1,500,000 gallons. During the time the water is being drawn from the reservoir it will also be possible to run the pumps, which will provide additional water, the amount of which will depend on their capacity. In all cases it is important that the water mains be of such sizes as will furnish the required amount of water at the desired locations during the time of heaviest flow with a reasonable amount allowed for friction loss.

Sprinklers. In this paper no mention has been made of water supply for automatic sprinkler systems in buildings. Although automatic sprinklers are very important as a means of fire protection, the amount of water required for them is not very large, and does not constitute very much of the total amount required for all purposes. Such systems are rather a means of reducing the amount of water necessary for proper fire protection by helping to keep the fire under control until the fire department arrives, and sometimes by extinguishing it entirely.

Maintenance and reserve capacity. In addition to the proper design of a water works plant it is of utmost importance that the mechanical equipment, fire hydrants, gate valves and other appurtenances, be maintained at a high state of efficiency so as to be reliable and always ready to perform their proper functions. There should be a thorough and systematic method of inspecting all equipment with special emphasis on fire hydrants in freezing weather. Pumps and engines or motors should consist of at least two separate units, each of sufficient capacity to take care of all requirements, so that if one unit is out of order on account of breakdown or repairs, the other unit will be able to furnish the required amount of water.

Value of fire protection. The fire protection service performed by the water works as well as its other functions, should have its just share of the operating expenditures balanced by operating receipts. In order to strike such a balance, the value of this service or the cost of furnishing it must in some way be determined. Many standards

for determining the value or cost of furnishing fire protection have been used by various municipalities, and in many instances it has been neglected altogether. In order to arrive at an equitable basis for determining such value, it is necessary to consider the difference in the design and operation of a system necessitated for the purpose of furnishing fire protection.

In a large city the requirements for fire protection do not play as large a part, relatively, in the design of a system as they do in a small city, except in certain details, such as fire hydrants, the size of mains, and, to some extent, the capacity of the pumping equipment, because in a large city the requirements for private and public use are usually very large, and constitute the greater portion of the total capacity that must be provided. In smaller cities, except the source of supply, as far as construction is concerned, the fire protection requirements determine nearly all the important features and include the pressure to be maintained, the size of the storage reservoir, the size of mains, and the pumping plant. These portions of the plant could be made much smaller and much less expensive were it not for the fire protection requirements.

The portion of the entire physical property of a water works plant involved in fire protection has been estimated by competent authorities to be as high as 80 per cent. The National Board of Fire Underwriters estimates that the percentage of cost of a distributing pipe system, chargeable to fire protection service for various size cities, is as follows: One having 10,000 population, 56 per cent; 50,000 population, 29; 100,000 population, 17½; 300,000 population, 4. Of the entire cost of the plant chargeable to fire protection service the estimate is as follows: 10,000 population, 60 per cent; 50,000 population, 32; 100,000 population, 23; 300,000 population, 13. Other authorities have given higher proportions as the cost of this service, especially for larger cities. The investigation of the cost of furnishing fire protection to a section of Greater New York for a population of about 400,000 people using an average daily supply of 38,000,000 gallons of water served by a private water company, showed that only 3 per cent of the total investment and 15 per cent of the operating expenses were attributable to fire protection, but with allowance for depreciation and interest on investment, the cost of fire protection was found to be approximately 21 per cent of the total cost of furnishing water by this company.

Metcalf, Kuichling and Hawley, in their paper[3] on "Reasonable Return for Fire Hydrant Service" make this statement:

The cost of the portion of the water works plant involved by fire protection service probably constitutes from 60 to 80 per cent of the entire cost of the property in the case of communities having less than 5000 population, 20 to 30 per cent in communities of 100,000 population, more or less, and perhaps 10 to 20 per cent in case of our large cities.

It is certain that the cost of furnishing fire protection constitutes such a large part of the total cost of the plant, and the value of the water works share in furnishing this protection is of sufficient importance to warrant special attention by municipalities.

For fire protection the amount of water consumed is very small, therefore, the value or cost of the service cannot be measured by the amount of water consumed, but must be derived from the cost of the additional construction and equipment required, and the maintenance of such additions. That part of the water works plant chargeable to fire protection consists of the additional pumping capacity, increased size of water mains, larger storage facilities, and the cost of hydrants. The approximate cost, therefore, of fire protection consists of the following items: The interest on the additional investment necessary in the water works plant by reason of the increased amount of construction required as stated above, and the maintenance of this portion of the plant. Also a certain amount of the attendant and inspection charges necessary in order to have the plant ready for operation at all times, day or night, which otherwise would not be necessary, especially if sufficient storage is provided for the ordinary consumption.

A conception of the value of fire protection service may also be obtained by comparisons of fire insurance premium rates under efficient fire protection and under no fire protection. This protection is made up of a fire department together with the water supply provided for this purpose, and the water works share of it consists of providing the agencies necessary for furnishing an additional amount of water under proper pressure over and above that necessary for the ordinary consumption, and the value of the water works part in it bears the same proportion to that of the fire department as the cost incurred by the water department in furnishing this service, bears to that of maintaining the fire department. The

[3] PROCEEDINGS, American Water Works Association, 1911, page 66.

difference in the insurance rates, however, is not the only value of good fire protection. There are other factors, such as the effect of economic waste resulting from loss of business, income and wages in the reconstruction following the fire, and the loss of property that cannot be replaced.

There are various methods used by municipalities in paying the water company or the city water department for its share of this service. A common method is to pay a monthly or annual hydrant rental of a fixed amount for each hydrant installed. While this method cannot be considered sound from either a business or technical standpoint, it is perhaps the simplest way of paying something for the service. There are valid objections to this method, one of these being that the number of hydrants used multiplied by a stipulated amount does not represent the cost nor the value of the service, but perhaps the greatest objection to it is that it will tend to prevent the installation of the proper number of fire hydrants required for good fire protection in order to save on the annual hydrant rentals. It is believed that a more desirable method of paying would be an annual lump sum based upon the cost of the service to the water company or city water department, and upon condition that the city should control the location and number of hydrants to be maintained. This lump sum should be revised from time to time in order that it may be equitable, and provide for additional service as the system is enlarged. There should be no objection, however, to dividing this amount by the number of hydrants in use, and calling it hydrant rental, provided the number of hydrants were not to be reduced below the requirements for good service.

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